The LUCID-2 Detector

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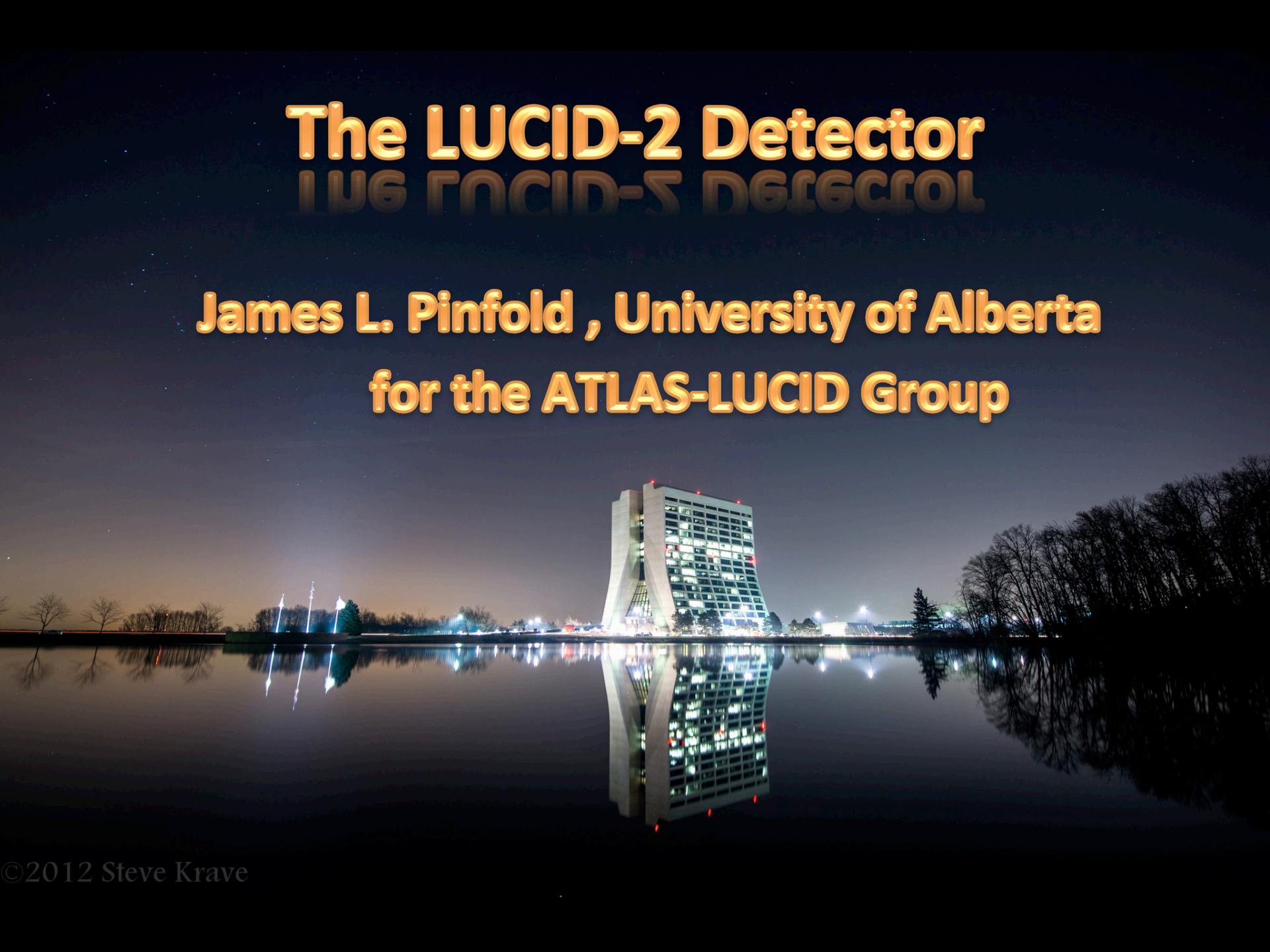
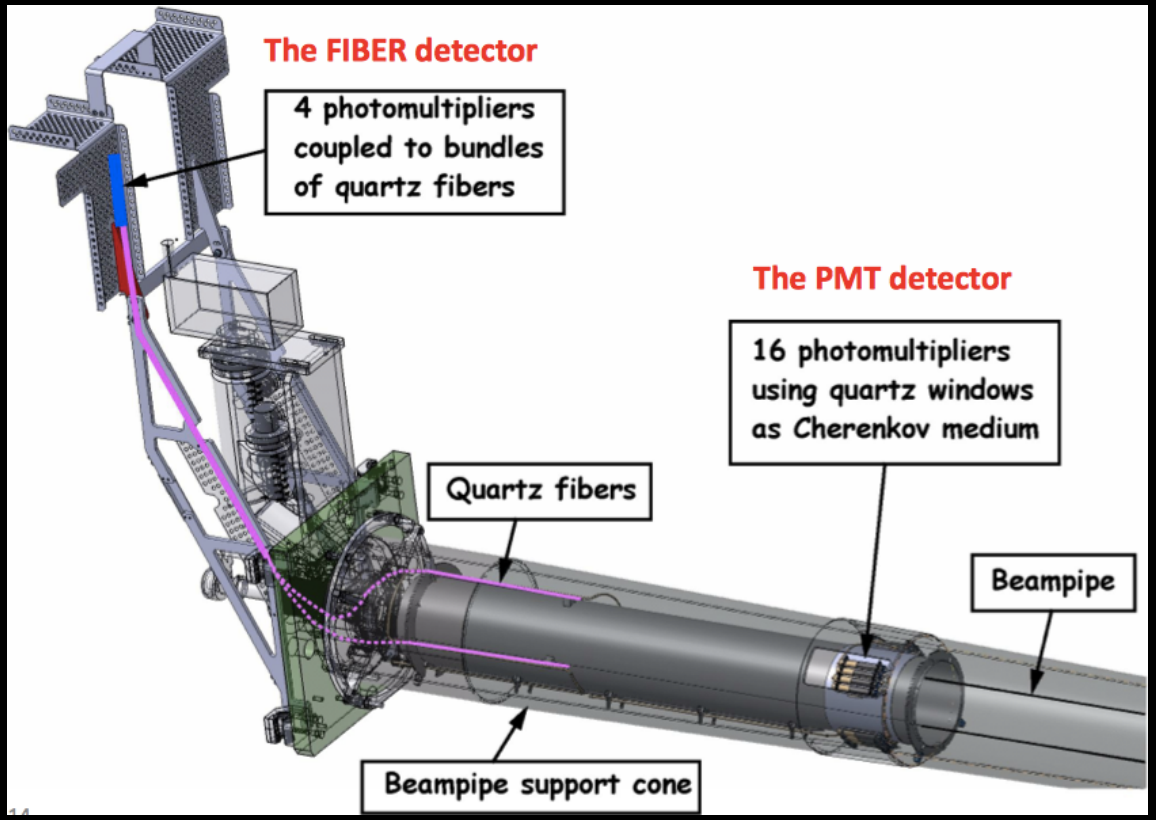
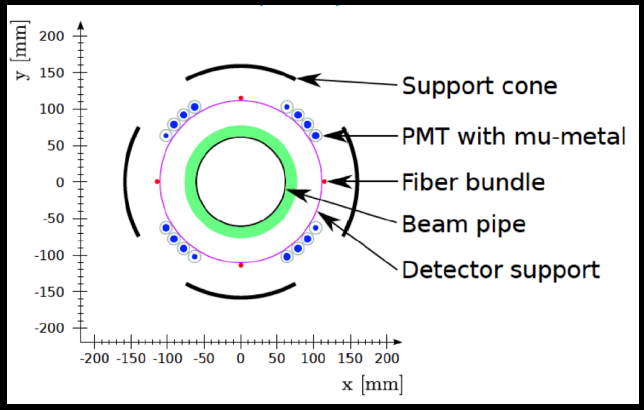
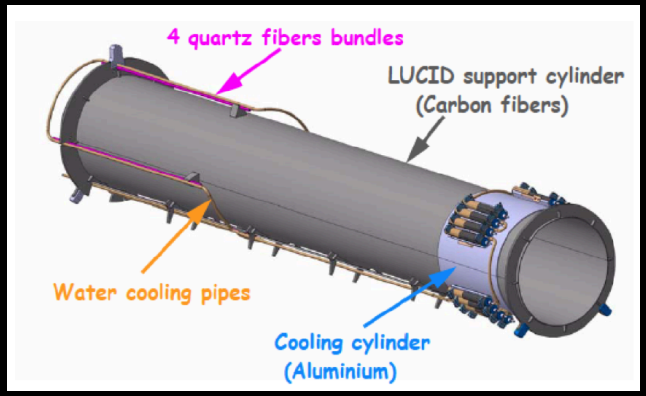
for the ATLAS-LUCID Group



LUCID-2 – ATLAS Luminosity Monitor
(LUminosity Cerenkov Integrating Detector)

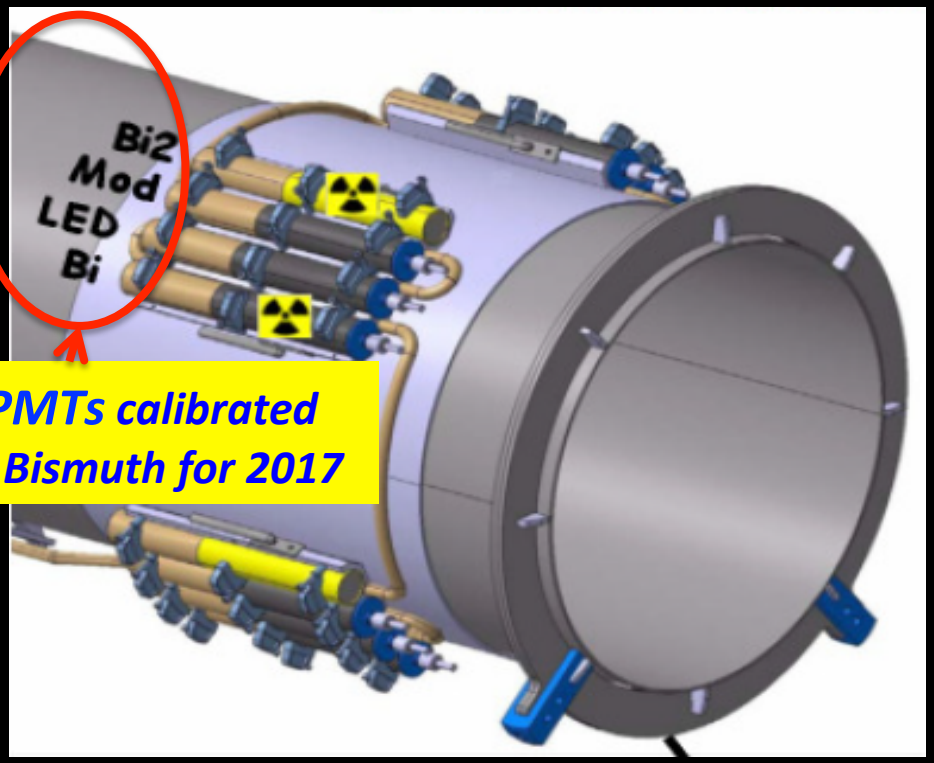




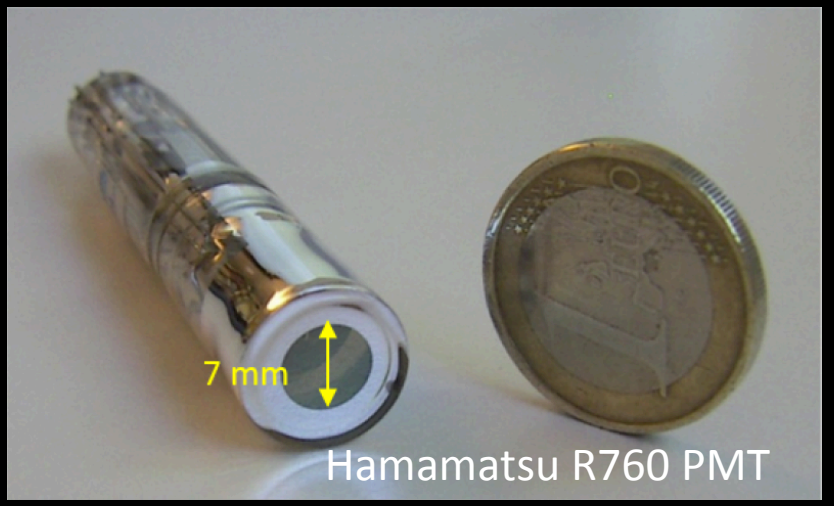


- *LUCID is a Cerenkov detector sensitive to particles from the LHC-collisions. It is composed of two modules around the beam-pipe at ±17m from from the ATLAS IP*

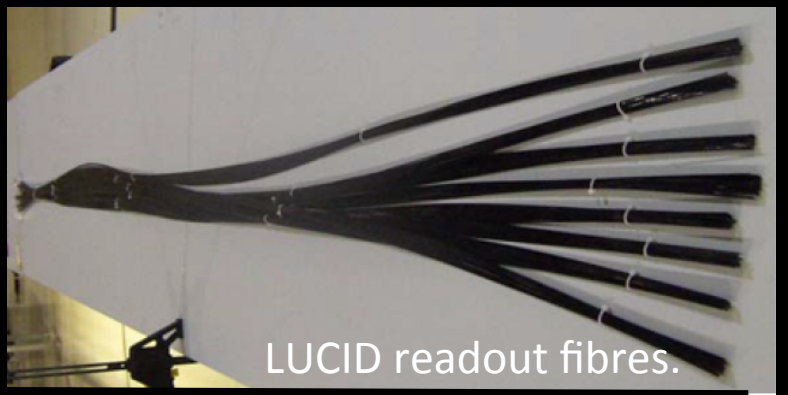
LUCID-2 Sensors



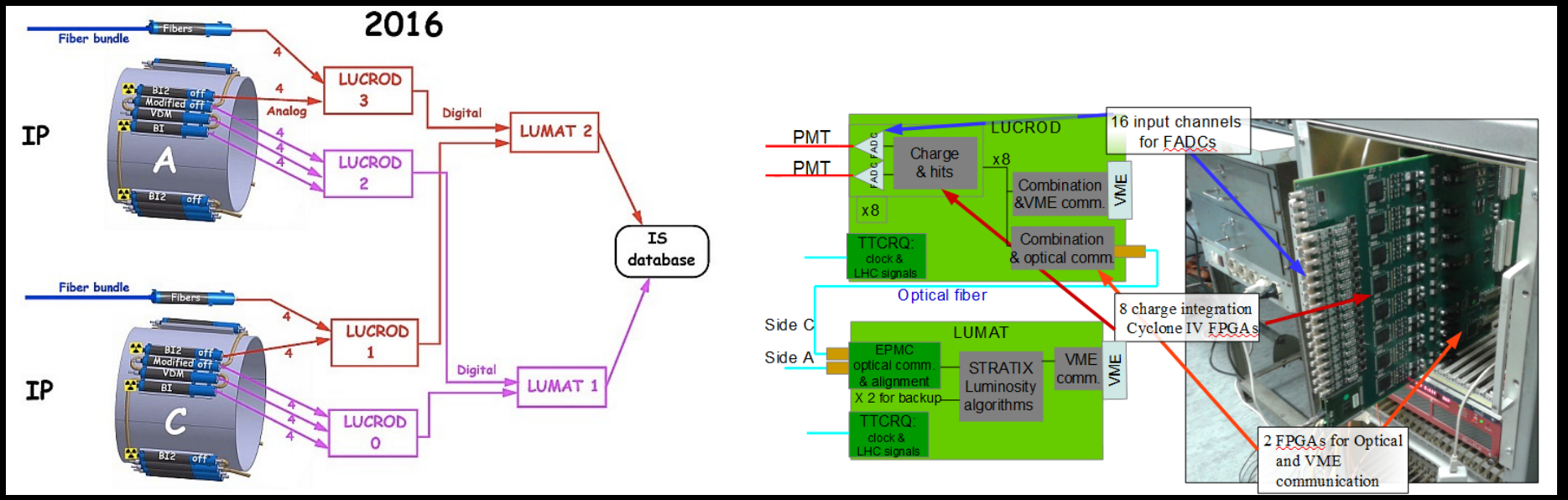
All PMTs calibrated wih Bismuth for 2017



- *Sensors – 4 groups of 4 PMTs*
  - *4x10 mm window PMTs (calib. ^{207}Bi)*
  - *4x10 mm window PMTs (calib. with ^{207}Bi)*
  - *4x7mm reduced window (calib.with ^{207}Bi*
  - *4x10 mm spare PMTs (calib. with ^{207}Bi*
  - *4 quartz fibre "calos" readout by PMT in low radiation area (CALIB. WITH LEDS)*



LUCID-2 Electronics

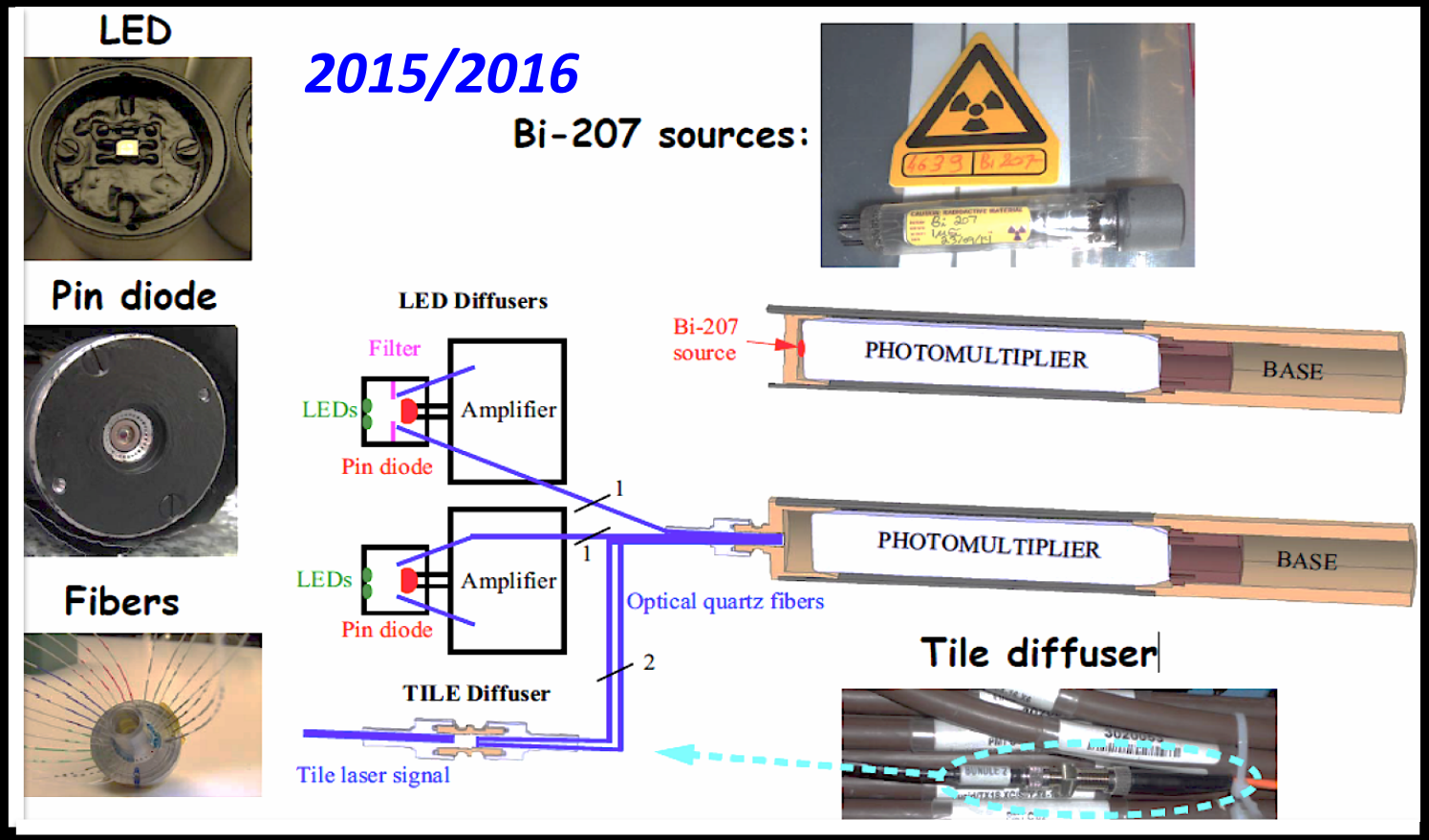


- *4 custom-made VME boards (LUCROD) placed ±17 m from the PMTs provide hit counting and charge measurement (insensitive to pile-up & prop. to lumi.) at each bunch crossing.*
  - *FPGAs integrate PMT signals over each bunch crossing*
- *2 LUMAT boards correlate hits from each side of LUCID to produce online and offline lumi measurements based in 12 algos*

Radiation Hardness

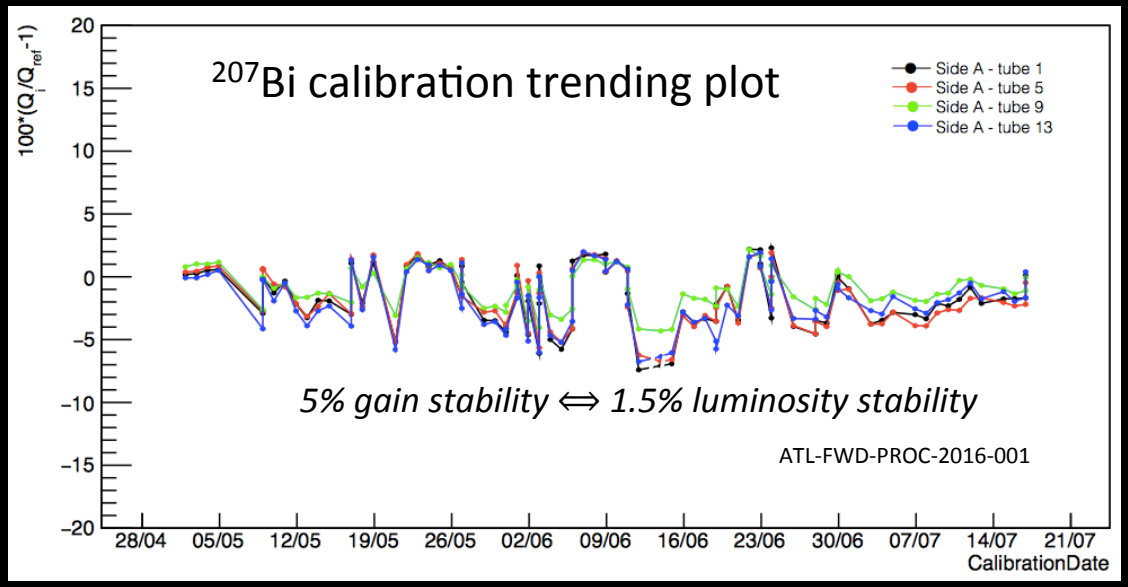
- *PMTs test to 200 kGy using the CALLIOPE ^{60}Co source and…*
- *PMTs tested up to ~ 2.6 x 10^{14} n/cm^2 using the TAPIRO facility*
- *This is the radiation dose expected for LHC RUN-2*
- ***No obvious radiation effects on the PMTs***

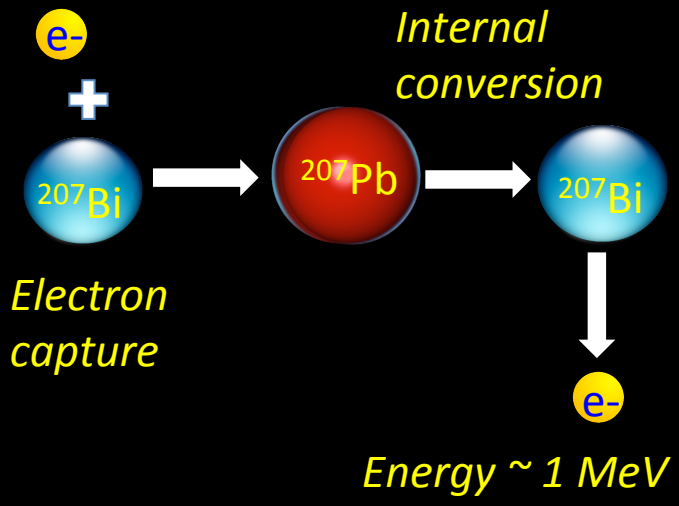
LUCID-2 Calibration



- *All PMTs now calibrated with ~1 MeV electrons from 207-Bi internal conversion*
- *Fibres Calos: now calibrated with LED pulses (stability monitored by Pin Diode)*

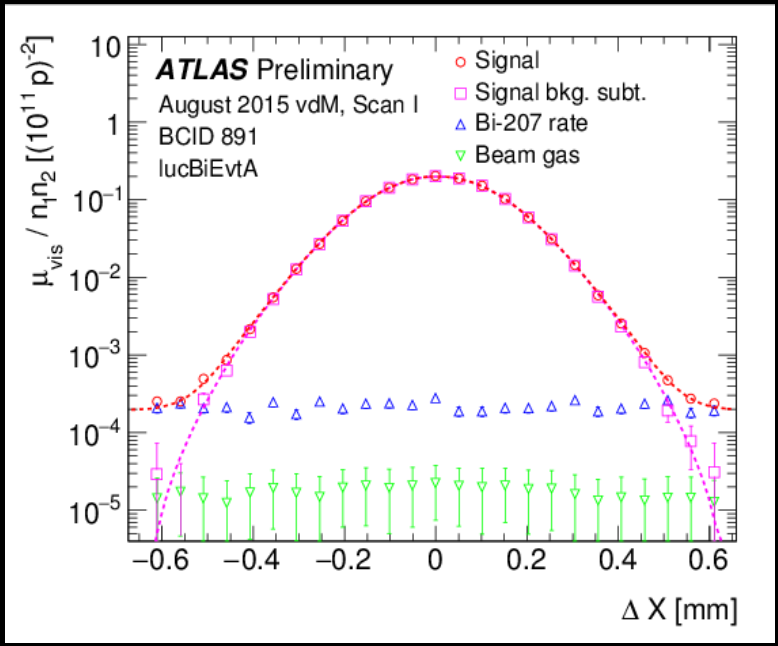
The Bismuth Calibration

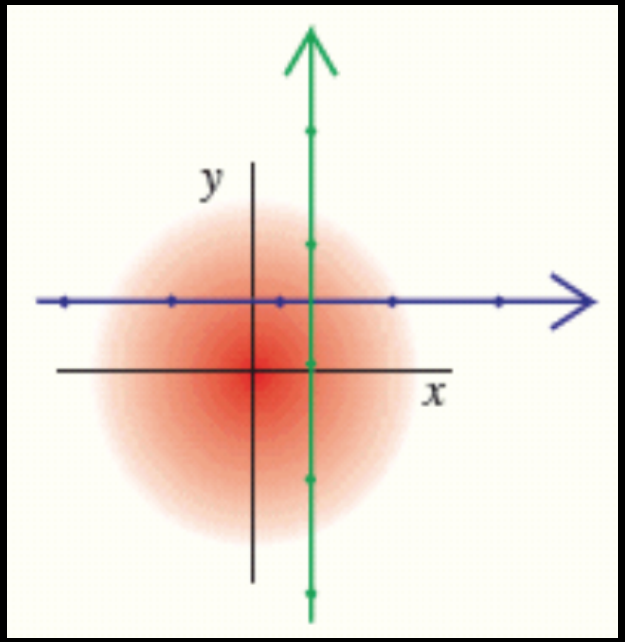




- *^{207}Bi now deposited on the window of all PMTs*
  - *Intensity of source is small compared to expected event rate but enough to calibrate in a few minutes when there are no interactions in ATLAS*

Absolute Luminosity Calibration

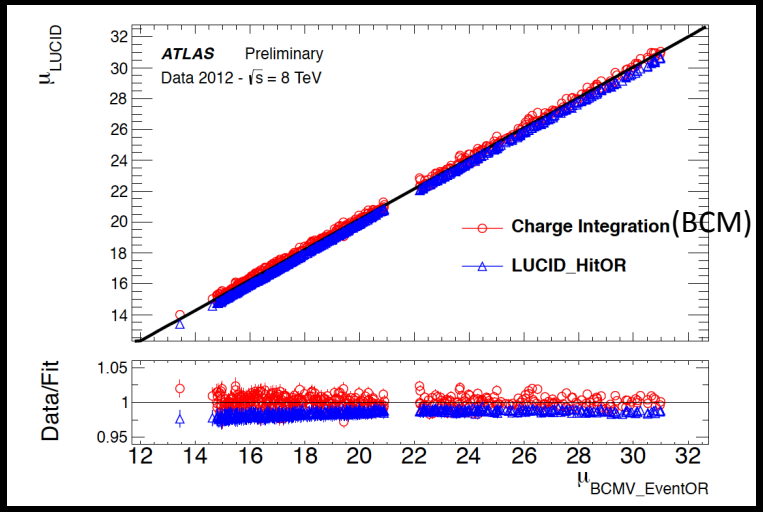




Bi-207 dies not spoil the precision of the VdM scan

- *Calibration:*
  - *The absolute calibration constant is measured for each algorithm and sensor type during dedicated LHC fills*
  - *The Van der Meer (VdM) scan technique is used (sweeping beams transversely across each other in a simple x/y scan (RH diagram)*

Luminosity Algorithms



- *LUCID-2 Exploits 2 Different kinds of algorithm:*
  - ***Hit and event counting algorithms*** *e.g. EventOR ($n_{hit} \geq 1$ in detector)*

$$L = \frac{f_r}{\sigma^{vis}} \sum_{i=1}^{n_{BC}} \mu_i^{vis}$$

Detected mean number of hits/events

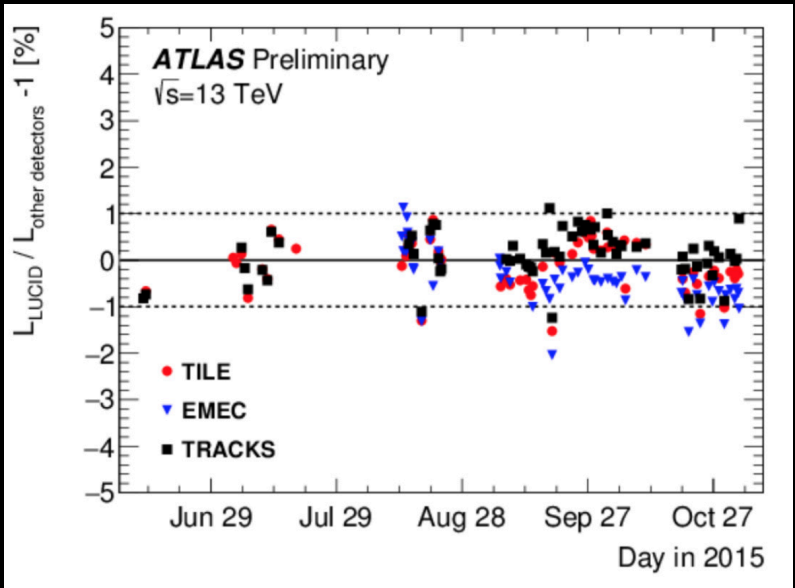
Calibration constant obtained from The VdM scan

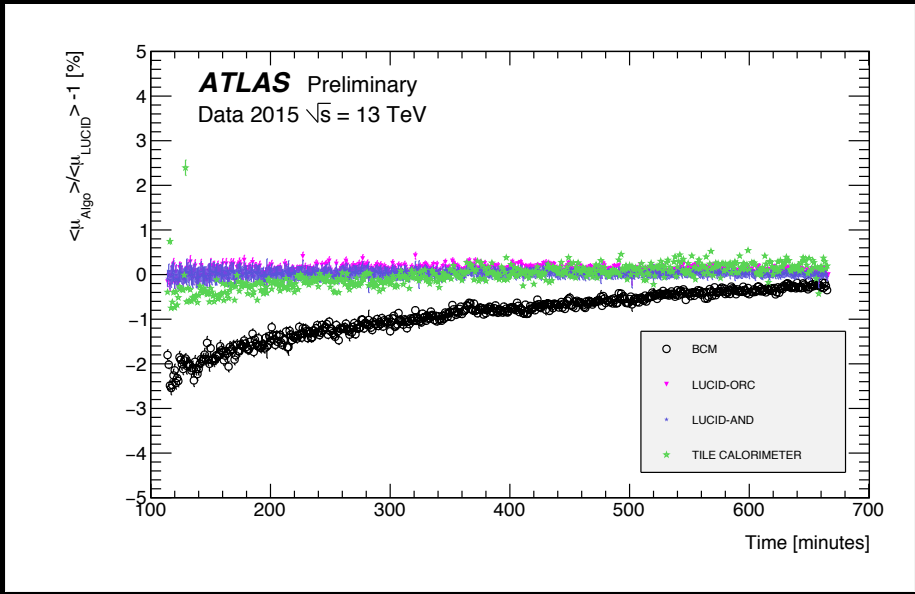
  - ***Charge Integrating algorithms****: measurement of the charge in the PMTs - proportional to luminosity.*

$$L = \frac{1}{K_{cal}} \sum_{i=1}^{n_{BC}} Q_i$$

Charge measured by PMT

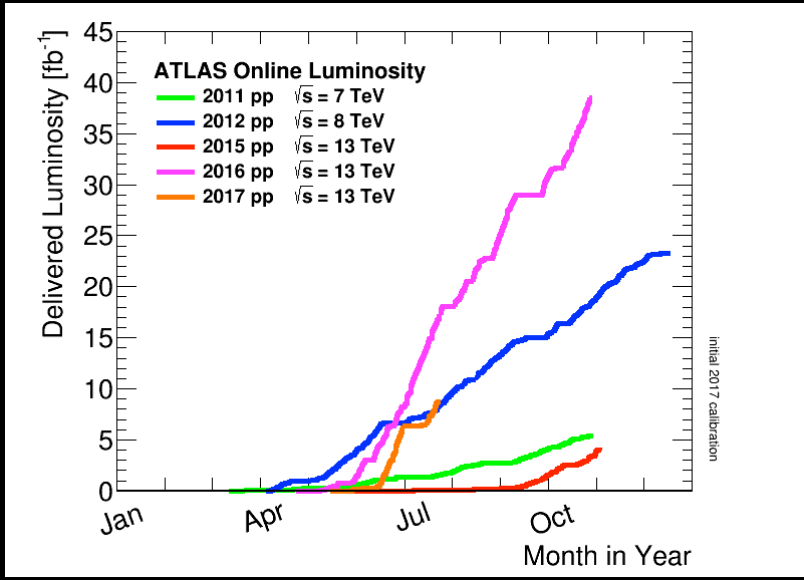
Luminosity Measurement Run 2

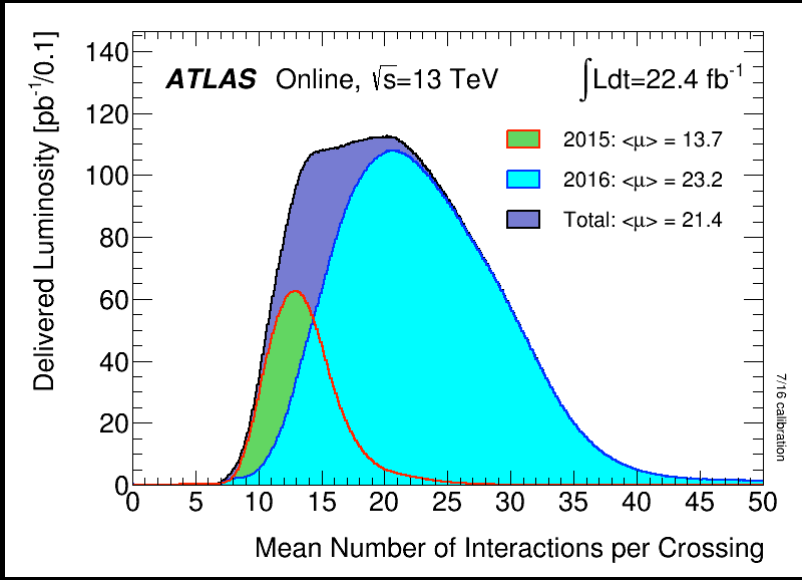




- *LEFT - Comparison of methods of lumi determination in ATLAS*
- *RIGHT - Ratio of μ the <#inelastic pp collisions/bunch crossing> from different ATLAS luminometers, to that reported by the forward (A) arm of the LUCID detector:*
  - *The backward arm of LUCID (LUCID-ORC),*
  - *The LUCID coincidence algorithm (LUCID-AND)*
  - *The luminosity determined by the TILE calorimeter (consistent within ±0.4% or better).*
  - *The BCM detector underestimate the luminosity by as much as 2 % early in the fill.*

Precision of Luminosity Measurement





Error on ATLAS luminosity in 2015

Error	50 ns	25 ns
Calibration error	1.66%	
Error in the calibration transfer correction	0.8%	0.9%
Run to run stability uncertainty	1.0%	
Total systematic error	**2.1%**	

← VdM Calibration

← LUCID uncertainty

Preliminary estimate of lumi. error in 2016 ~ 2.2%

Final Words

- *An accurate determination of the luminosity is essential in any high-energy physics experiment providing cross-section measurements.*
- *The change of LHC running conditions for 13 TeV running has required a complete LUCID redesign of detector & electronics – hence LUCID-2.*
- *Currently, LUCID-2 provides the official luminosity figures for ATLAS.*
  - *Preliminary results of the analysis shows a long-term stability of the LUCID at the level of ~1% and a total systematic uncertainty on luminosity measurement of ~2%*
- *Thanks to the different detection methods implemented, LUCID-2 is expected to provide important inputs for the luminosity detector for Hi luminosity LHC (~2025)*